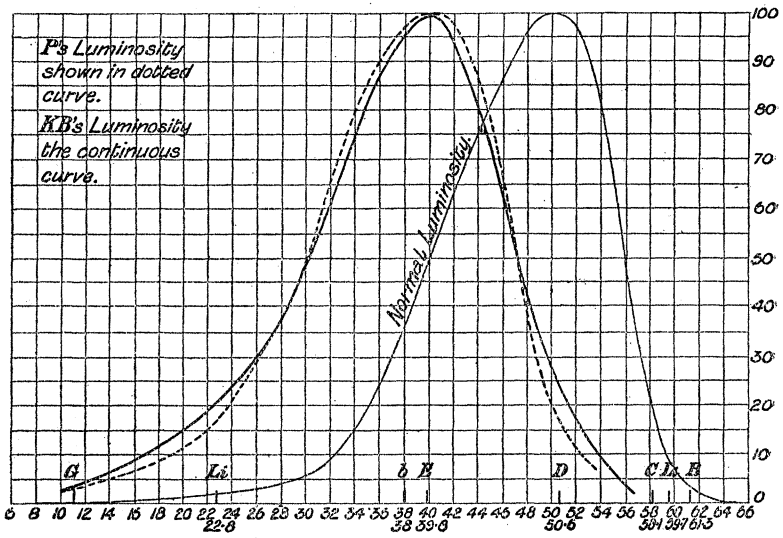
employed. The slight divergence on the left-hand side of the curve from that of P is probably due to his colouring matter in the yellow spot. Attention must be again called to the fact that these curves are practically identical with those obtained by the normal eye when it measures a spectrum of very feeble luminosity, and also agree with



the results obtained by measuring the diminution of each ray when it first becomes invisible, and making a curve of the reciprocals of the numbers, taking the highest point of it as 100. This is clearly shown in Part III, "Colour Photometry."* It may be mentioned the scale of the prismatic spectrum employed is the same in this communication as in that paper, the wave-lengths of each scale number being given in it.

"On the Influence of the Temperature of Liquid Air on Bacteria." By Allan Macfadyen, M.D. Communicated by Lord Lister, Pres. R.S. Received December 15, 1899,—Read February 1, 1900.

The experiments of Dr. Horace T. Brown and Mr. Escombe† have shown that no appreciable influence is exerted upon the germinative power of seeds, when exposed for 110 hours to the temperature of

* 'Phil. Trans.,' A, vol. 183, 1892.
† 'Roy. Soc. Proc.,' vol. 62, 1898, p. 160.

liquid air (– 183° C. to – 192° C.). The results were equally negative in the recent experiments of Sir W. Thiselton-Dyer,* in which seeds survived exposure for upwards of six hours to the temperature of liquid hydrogen (– 250° C. to – 252° C.).

The following investigation on the influence of the temperature of liquid air on bacteria, was carried out at the suggestion of Sir James Crichton Browne and Professor Dewar. The necessary facilities were most kindly given at the Royal Institution. The experiments were conducted under the personal supervision of Professor Dewar, and he has asked me to put the results on record, although it must be acknowledged that the essential features of the investigation are due to him.

The bacteria employed were selected from the stock of the Jenner Institute of Preventive Medicine, where the results were also controlled. Pure cultures of the several micro-organisms were employed, and the series included typical representatives of saprophytic and parasitic bacteria. The organisms chosen possessed varying degrees of resistance to external agents—the extremes in this respect being represented by the very sensitive spirillum of *Cholera Asiatica* and the highly resistant spores of *B. anthracis*.

Ten organisms were used for the experiments, viz. :—*B. typhosus*, *B. coli communis*, *B. diphtheriæ*, *Spirillum choleræ Asiaticæ*, *B. proteus vulgaris*, *B. acidi lactici*, *B. anthracis* (sporing culture), *Staphylococcus pyogenes aureus*, *B. phosphorescens* and *Photobacterium balticum*.

The cultures of the organisms were young and vigorous, and were tested both on solid and in fluid media, viz. :—Nutrient gelatin, agar-agar, potato and peptone broth.

The cultures on these media were simultaneously exposed to the temperature of liquid air for twenty hours (– 182° C. to – 190° C.). They were then carefully thawed and examined. The results may be briefly stated. In no instance, whether on solid or in liquid media, could any impairment of the vitality of the micro-organisms be detected. The fresh growths obtained from the exposed tubes were normal in every respect, and the functional activities of the bacteria were equally unaffected. The colon bacillus produced its typical effects—such as the curdling of milk, the fermentation of sugar and the production of indol; the *Staphylococcus pyogenes aureus* retained its pigment producing properties and the anthrax spores their pathogenic action on animals. The photogenic bacteria preserved their normal luminous properties. These photogenic properties are intimately connected with the functional activities of the cells. The cells emit light which is apparently produced by a chemical process of intracellular oxidation and the phenomenon ceases with the cessation of their activity. These organisms therefore furnished a very happy

* 'Roy. Soc. Proc.,' vol. 65, 1899, p. 361.

test of the influence of low temperatures on vital phenomena. Their cultures, when cooled down in the liquid air for twenty hours, became non-luminous, but on re-thawing the luminosity returned with unimpaired vigour as the cells renewed their activity. Watery emulsions of the photogenic bacteria, on immersion in liquid air for a few minutes, ceased to emit light, but on withdrawal the luminosity reappeared in a very short time. Strips of filter paper soaked in the watery emulsions and brightly luminous were immersed directly in the liquid air with similar results. The sudden cessation and rapid renewal of the photogenic properties of the cells, despite the extreme changes of temperature, was remarkable and striking.

The following experiment was made:—Fifty litres of the laboratory air about six feet from the ground were liquefied at atmospheric pressure in a glass bulb by means of boiling liquid air *in vacuo*. The temperature reached was about – 210° C. The bulb was then sealed off, the contents being still at a temperature below zero, and was subsequently opened and washed out with sterile broth. A series of plate cultures were made from the broth on nutrient gelatin, agar-agar and sugar agar, and were incubated under aërobic and anaërobic conditions at 22° and 37° C. for a period of ten days. The anaërobic plate cultures remained sterile. The aërobic plates yielded forty-four organisms which had survived an exposure to – 210° C. The organisms were representative types of those to be usually met with in the air, viz., moulds, bacilli, cocci, torulæ and sarcinæ.

It may also be mentioned that a sample of yeast cell plasma (Buchner's zymase) subjected to – 182° C. to – 190° C. for twenty hours, retained its peculiar properties unchanged, viz., as regards the production of CO_2 and alcohol.

The above experiments show that bacteria may be cooled down to – 190° C. for a period of twenty hours without losing any of their vital properties.

Further experiments are in progress with the above-mentioned and with other micro-organisms, exposed to the temperature of liquid air for still longer periods of time, as well as to that of liquid hydrogen. These experiments will form the subject of a future communication.